INTRODUCTION
It has been reported that implant loosening is a common complication of satin matte finished or grit-blasted cemented femoral implants [1]. An early feature of femoral implant loosening is the unintentional debonding of the implant-cement interface [2]. Failure of the implant-cement bond causes the implant to become mechanically loose, resulting in unintended micromotion at the cement-bone interface [3]. This movement between the cement and bone will initiate bone resorption and lead to gross loosening of the implant. It is therefore critical to have strong adhesion between the stem-cement interface to avoid loosening and ultimately failure of the implant.

In this study we developed a test model that isolated the interaction at the cement-stem interface to determine the adhesion strength of the stem to a cement mantle. We used a well accepted stem design with a satin matte finish [4] to measure the force required to disrupt the cement-stem interface.

METHODS

Specimen Preparation
The stems were aligned vertically within a PVC liner with the distal tip pointed down and encased in bone cement up to its medial resection point.

Specimen Testing
The distal plate was removed from the stem/cement construct to expose the stem’s centralizing hole. The entire assembly was then inverted. The face of the proximal collar was supported by vise jaws, which resulted in a fully supported fixture but allowed unimpeded egress of the stem from the cement during testing. An appropriately sized dowel pin was inserted into the stem’s centralizer hole and an axial load was applied to the dowel pin via a single axis Instron 456 testing system (Instron, MA) fitted with a 100 kN load cell. The cross-head speed was set at 5 mm/min and the reactive force and cross head extension values were recorded. Testing was stopped once the maximum load was achieved as indicated by a sharp drop in push out force. From this data maximum push-out force and extension at maximum force were determined.

RESULTS
An average compressive force of 5807.7 ± 85.9 N (range: 4612.3 – 6701.1 N) was required to dislodge the cemented stems from their cement mantles. The maximum compressive force recorded for the test was assumed to be the force at which the stems “dislodged” from the cement mantle. Testing was stopped at an extension 0.2 – 0.4 mm after the peak compressive value to ensure that the peak value was, indeed, the maximum compressive value.

The average extension at the point of maximum compression was 1.0 ± 0.2 mm (range: 0.78 – 1.2 mm). The variation in extension was likely caused by slack in the fixturing and differences between starting extension values. The small displacement demonstrated the tight adhesion between the stem and cement before failure of the stem-cement interface occurred.

The mode of failure for all samples was disruption of the stem-cement interface. Visual examination of the samples post-testing showed that in all cases, the stem cleanly separated from the cement mantle; no cement remained on the stem, and all cement mantles remained intact.

DISCUSSION
Results from this test provide insight into the amount of force required to disrupt the stem-cement interface of a satin matte finished cemented stem. Results showed that the satin matte finish of the stem adhered to the cement, allowing the interface to withstand an average load of 5807.7 N before debonding. This load is greater than in vivo loads acting on the hip joint in a 220lb patient during normal walking [5].

An inverted model was used during testing to eliminate the influence of subsidence and “self-tightening,” or wedging, of the stem within the cement mantle. While this allowed the isolation of the stem-cement interaction, it is recognized that this does not represent a clinically relevant test scenario. The stem is designed to function in a clinically relevant model, with force acting in a distal direction, and it is expected that the stem-cement interface, if tested in a clinically relevant orientation, would withstand a greater load than that measured in this test.

This model may be further used in a comparative manner to assess the integrity of other implant-cement, coating-substrate, or coating-bone interfaces. Results from these tests could help to determine an optimized implant design that will strengthen the implant-cement interface and promote longevity of the implant.

REFERENCES